P.16 Electro-Hydrostatic Transmission and Control Technology for Modular D&D Manipulators

Joseph W. Geisinger (joewg@armautomation.com, 512-894-3534)
Derek D. Black (dblack@armautomation.com, 512-894-3534)
ARM Automation Inc.
14141 West Highway 290, Suite 700
Austin, Texas 78737

Abstract

Many D&D activities require the use of remotely operated tools for the inspection, characterization, and dismantlement of facilities and equipment. Automated and remote D&D operations demand extremely robust manipulators that can accommodate heavy payloads and generate high forces. The current solution to this challenging application, a hydraulic manipulator, has several drawbacks. The hydraulic power source consists of a large motor, pump, reservoir, and hoses that transport the pressurized supply and return fluid. The power source is heavy and noisy. The connecting hoses are difficult to handle and prone to leakage, which in a contaminated environment causes a serious mixed waste issue. A failure can result in a leak of gallons of fluid in an instant. Installation of the power source outside of the contaminated area creates a risk of transporting contamination across the boundary. Despite these drawbacks, hydraulic systems are used because they offer the highest volumetric force/torque density of any mature actuation technology at a reasonable cost. The DOE has many unique automation requirements that cannot be met by a single COTS monolithic robotic solution. Furthermore, developing a custom system from scratch is prohibitively expensive and time consuming. The solution to this problem is a modular architecture and system of pre-engineered actuators and links that can be quickly combined to create a manipulator suited to a task.

ARM Automation, Inc. (ARM) has realized the modular approach by developing an extremely compact, embedded electronic controller and actuator. To date, ARM has developed two sizes of electro-mechanical actuators (EMAs). These are suitable for tasks with moderately heavy payloads (10kg). Many D&D tasks, however, require higher payloads (over 50kg) and longer reaches. To meet these goals, actuators with increased torque capacity are needed. Under this development effort, the existing architecture will be extended with closed-loop electro-hydrostatic technology that combines the best of hydraulic systems (high torque) with the best of electro-mechanical systems (modularity, controllability, cleanliness). Traditional hydraulic systems power the actuator from a manifold and control actuator position with a spool valve. While this approach permits a single pump to power multiple actuators, it is energy intensive and suffers from the drawbacks described above. In a hydrostatic system, each hydraulic motor is matched to its own pump integrated into the same housing. Common examples are floor jacks and hydrostatic transmissions. This technology embodies the novel approach of position control of a hydrostatic actuator by servo-controlling the electric motor driving the pump rather than using a spool valve. A complete electro-hydrostatic actuator EHA) compatible with ARM's existing architecture will be developed. There will be no external hydraulic lines or connections and the volume of fluid contained in the actuator will be minimal. It is estimated that this design

will offer 3 - 5 times the torque density of ARM's current designs (which already are several times better than prior electro-mechanical actuators). Finally, as this actuator will be built using the same controller and architecture as ARM's EMAs, a manipulator can be readily constructed from a mix of electro-mechanical and electro-hydrostatic actuators.

In Phase I, the basic technology of an EHA control architecture and transmission will be evaluated and developed to determine the feasibility of this approach. Technical challenges are foreseen in two areas: controllability and packaging. To address the first, a control approach and algorithm will be developed and simulated using a mathematical model of the physical plant and control algorithm. Next, an EHA test bed will be designed and fabricated to verify the results of the simulation. A controllable load combined with torque, pressure, position and current transducers, and data-acquisition equipment will be used to evaluate actuator performance across its operating range. The packaging challenge lies in two areas. Most off-the-shelf hydrostatic transmission components are designed for use in applications where indestructibility rather than weight as the driving criterion. It is expected that significant weight savings will be realized by eliminating redundant housings, bearings, couplings, and fittings. The second part of the packaging challenge lies in the physical arrangement of a hydrostatic transmission with an adequate reduction ratio in a high-pressure housing. This will be addressed through evaluation and selection of the most appropriate hydrostatic technology (gerotor, helical screw, vane, piston, etc...) and conceptual design of a packaging arrangement.

The focus of Phase II is on the design and fabrication of a fully integrated EHA compatible with ARM's existing EMA architecture. This EHA will be a basic building block of a modular D&D manipulator. The technical challenge is anticipated to be the integration of the hydrostatic components in a compact lightweight package. The conceptual hydrostatic design of Phase I will be refined by working closely with a hydrostatic component vendor. Advanced materials and manufacturing processes may be applied. The motor and DISC (ARM's Distributed Intelligent Servo Controller) controller section are expected to remain very similar to ARM's modular EMAs. Depending upon the final layout, ARM's absolute position sensor may require repackaging. This unique sensor is mounted inside the gear train of the current EMA design to maximize packing efficiency. As with the conceptual EMA design, complete solid models will be built to aid in the complex 3-D design and maximize the use of all available volume.

In phase III, a completed manipulator, composed of EHA modules, will be tested at a DOE site to determine functionality, capability, and compatibility in the processing of nuclear materials. The realization of this goal will make feasible the construction of manipulators that can be configured with the performance capabilities and payloads associated with D&D tasks.

This is a new project that was initiated in October 2001. Work over the next year will focus on developing the EHA control architecture, as well as building a test-bed to demonstrate the feasibility of using an Electro-Hydrostatic transmission as a viable alternative to mechanical gear trains or pure hydraulic manipulators.